

## New NIST high intensity beamline for direct testing of optics carbonization from irradiated resists

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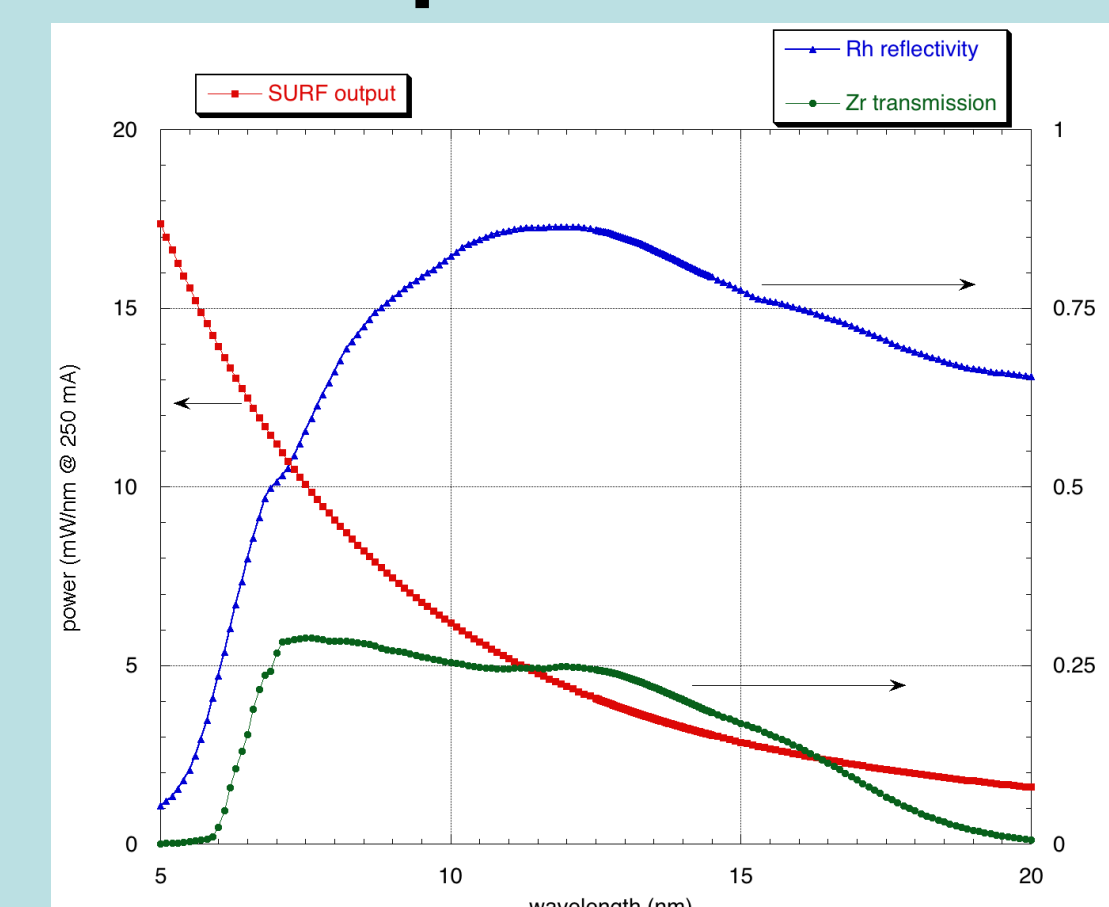
**NIST**  
National Institute of Standards and Technology  
Technology Administration, U.S. Department of Commerce

## Beamline features

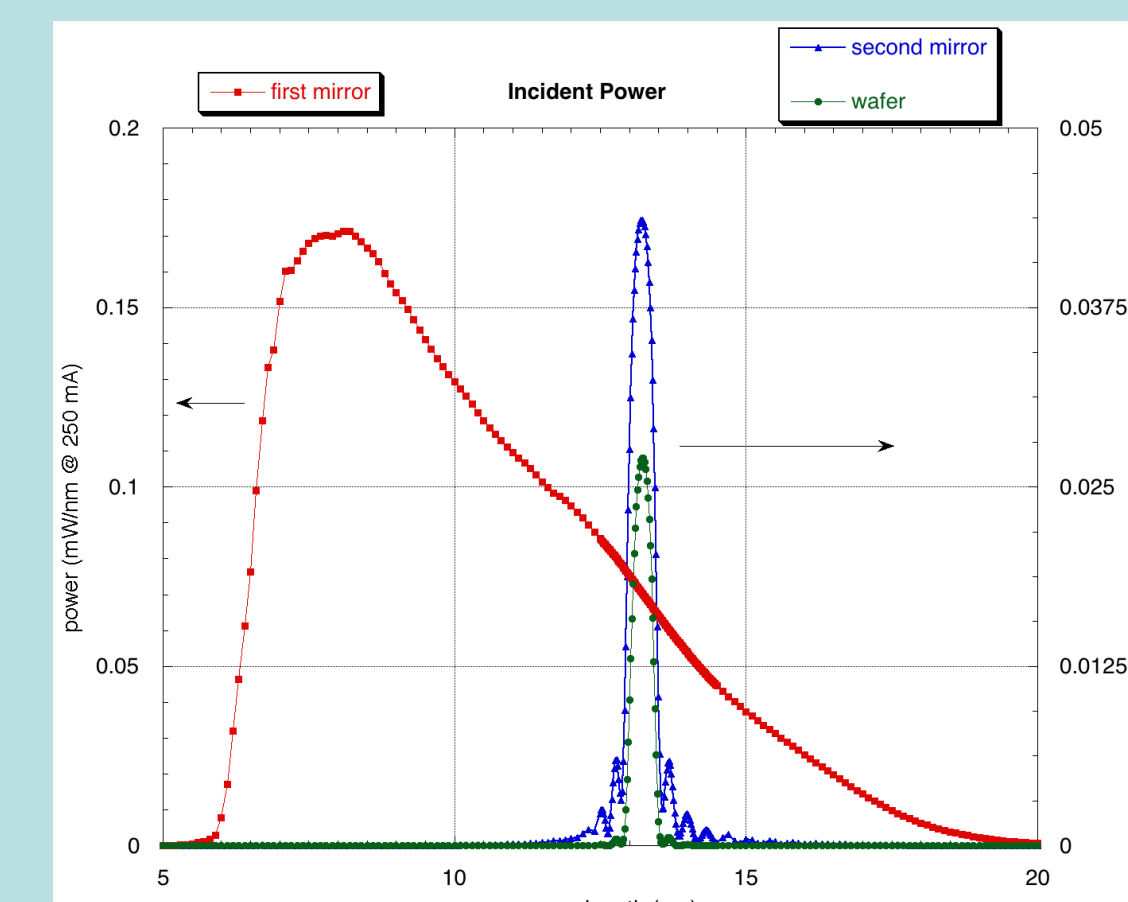
- Incorporates grazing incidence broadband (6 - 18 nm) mirror to demagnify EUV beam on witness plate.
- Sufficient intensity to provide mass limited deposition rates.
- Dual mirror design provides narrow band resist illumination and eliminates line-of-site exposure of witness plate. (see below)
- *In situ* broadband and narrowband power measurement to ensure accurate resist dose.
- Single-wavelength, Null-field Ellipsometric Imaging System (NEIS) monitors deposition in real-time during exposure.
- Wafer translation and rotation and spot oversampling to insure uniform wafer exposure.
- Narrow band 13.5 nm radiation to expose 200 mm wafer in <1hr.
- Integrated glovebox permits rapid cycle time for samples.
- Base pressure of the vacuum  $\sim 10^{-9}$  Torr.
- *Ex situ* H-atom pre-cleaning of witness plates.
- *Ex situ* XPS and spectroscopic ellipsometry of exposed witness plates.
- Facility expected to meet the requirements for ASML NXE resist qualification once NIST witness plate cleaning test is qualified.

## EUV illumination spectrum

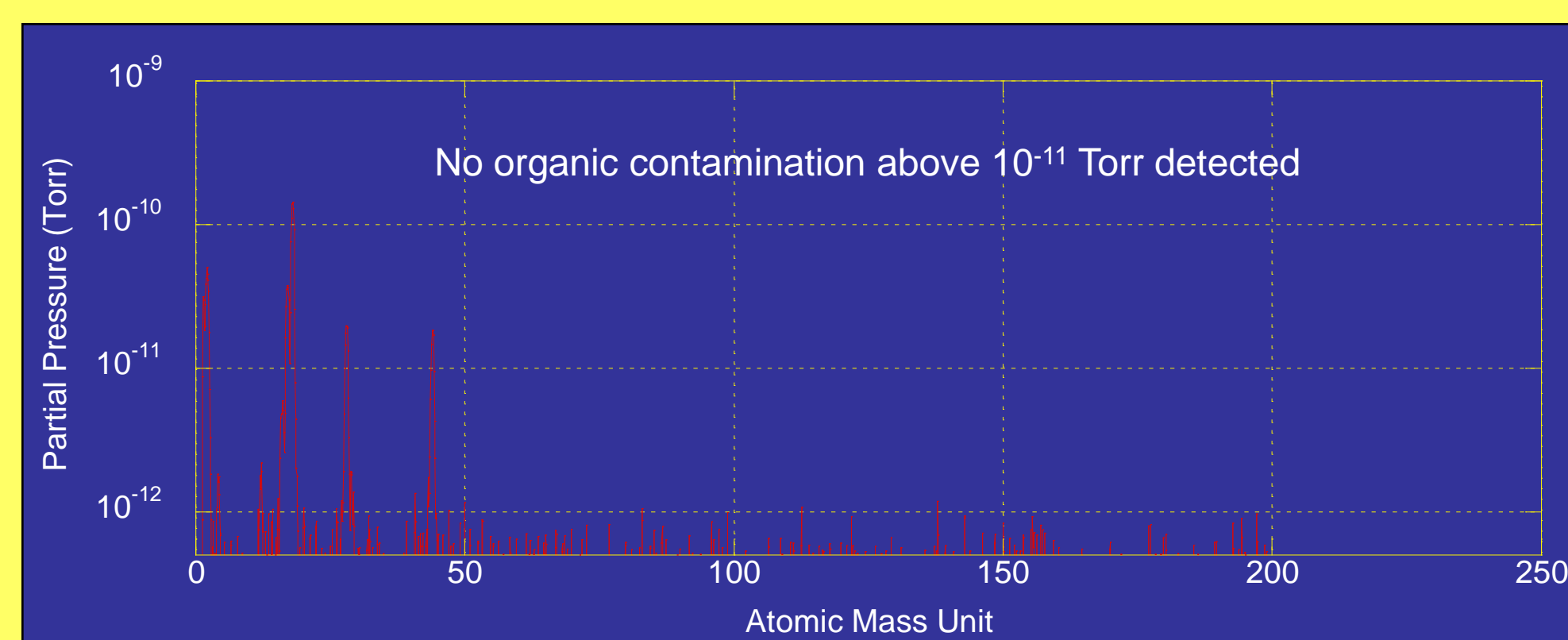
Calculated synchrotron output and measured optical component performance.



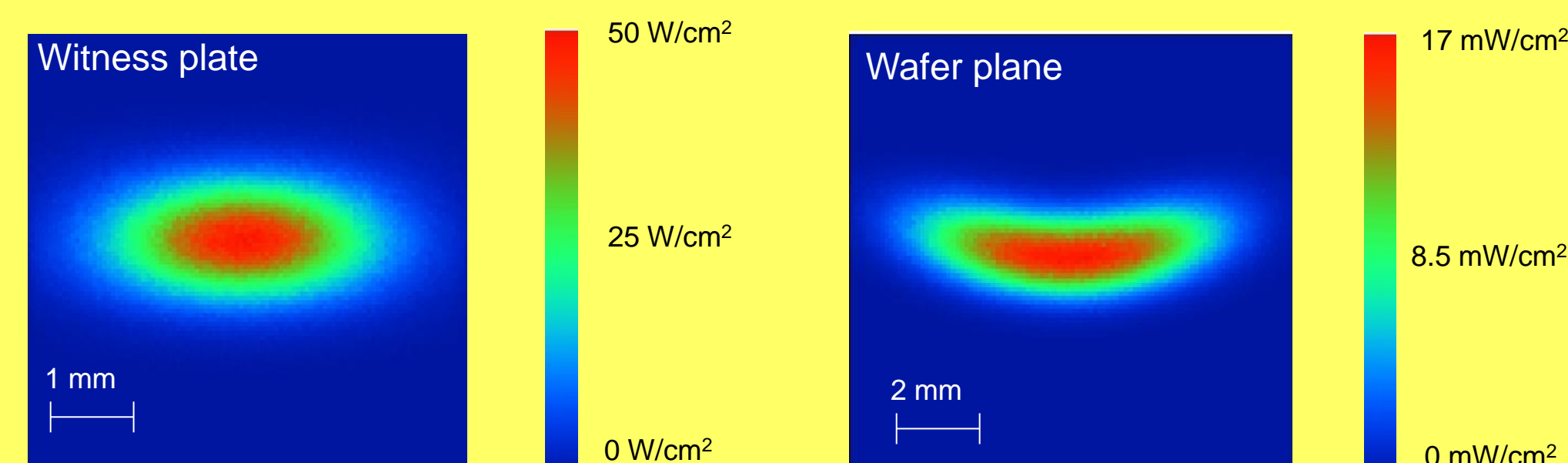
Spectral distribution of power on witness plate (red) and on resist (green). Maximum intensity on sample = 5 W/cm<sup>2</sup>. Intensity on resist = 17 mW/cm<sup>2</sup>.



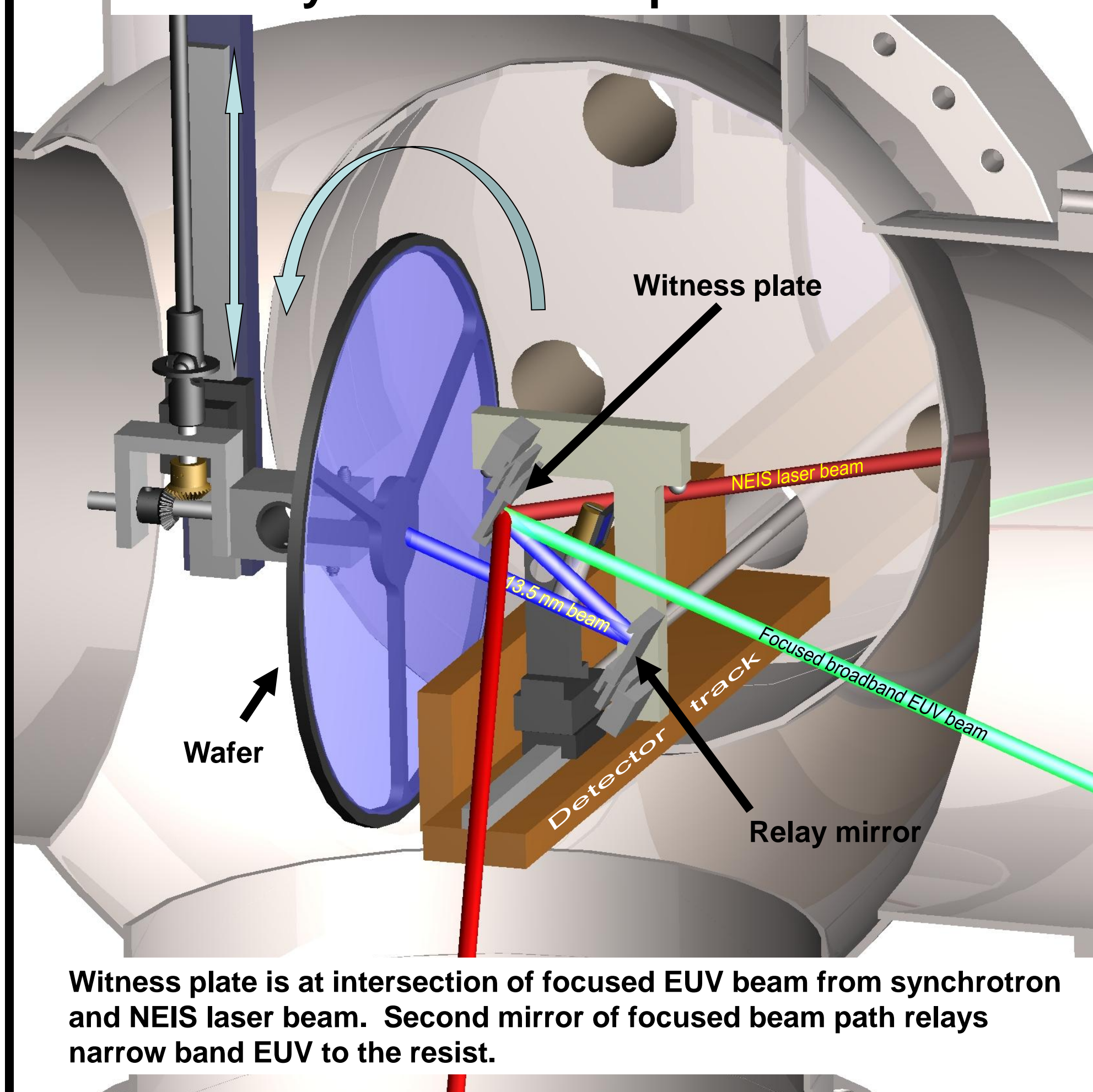
## RGA of base vacuum



## EUV beam profile



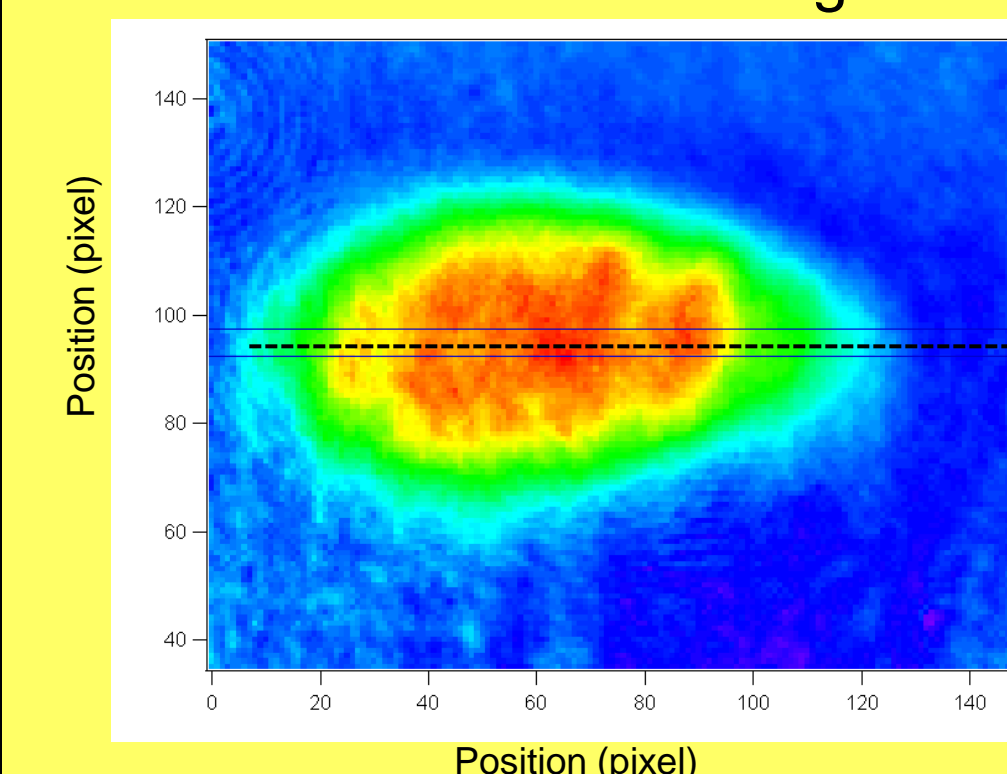
## Cut away view of the exposure chamber



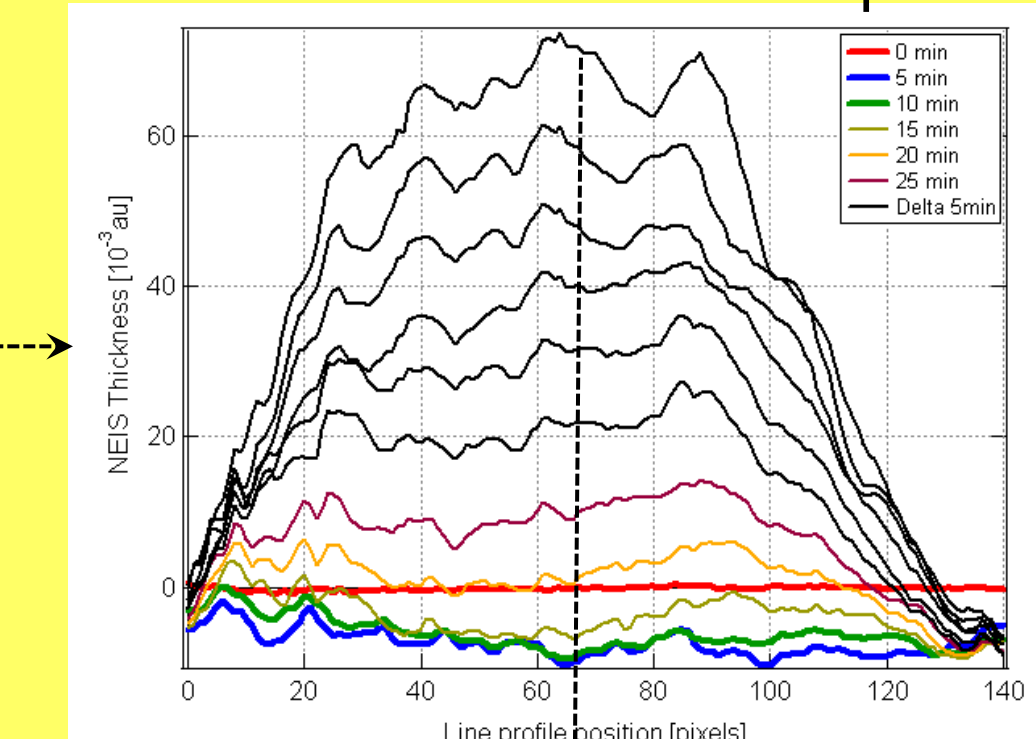
Witness plate is at intersection of focused EUV beam from synchrotron and NEIS laser beam. Second mirror of focused beam path relays narrow band EUV to the resist.

## Real time imaging of deposition process

Final NEIS image



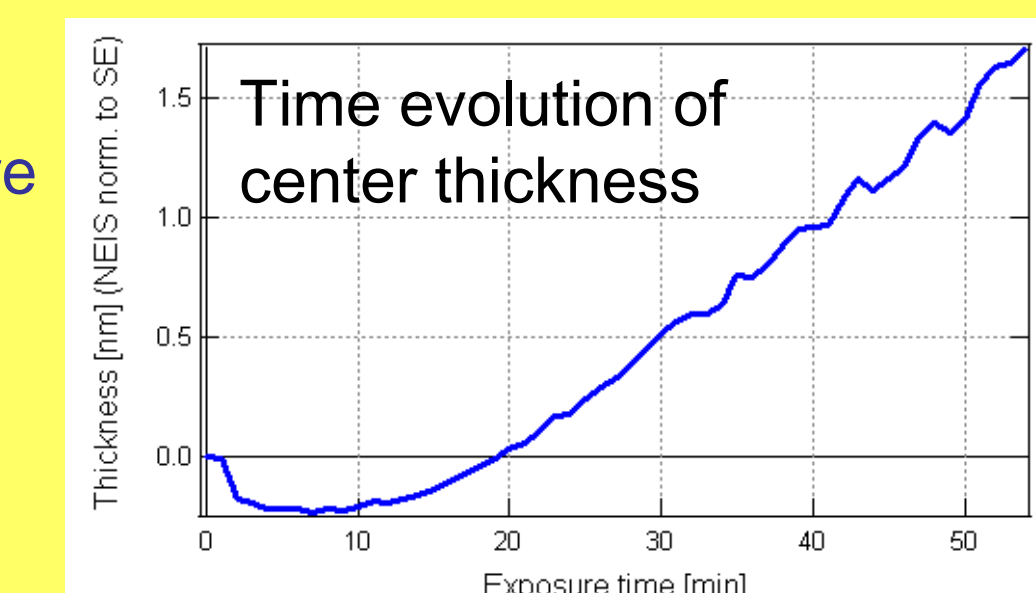
Time evolution of line profile



The NEIS thickness monitor provides a real-time measurement of carbon accumulation on the irradiated sample. In the NEIS data shown here significant contamination does not start until ~20 minutes into exposure. Subsequent growth rate appears constant.

Flat-topped profile indicates mass-limited growth.

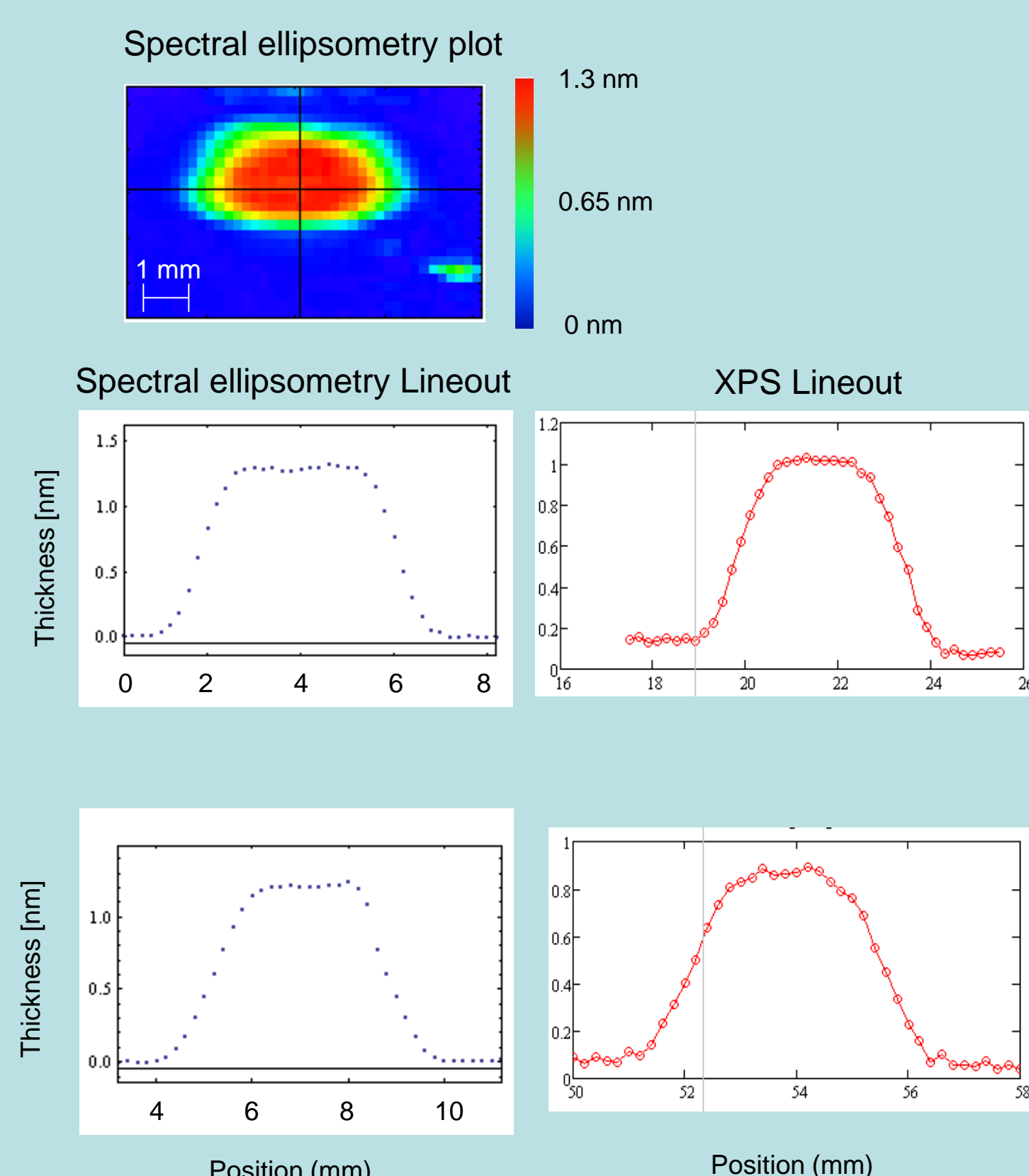
Center thickness evolution normalized to *ex situ* spectral ellipsometry.



## Post-exposure analysis

*Ex situ* spectral ellipsometry analysis of deposition on witness plate showing mass limited behavior at the highest intensities in the irradiated spot.

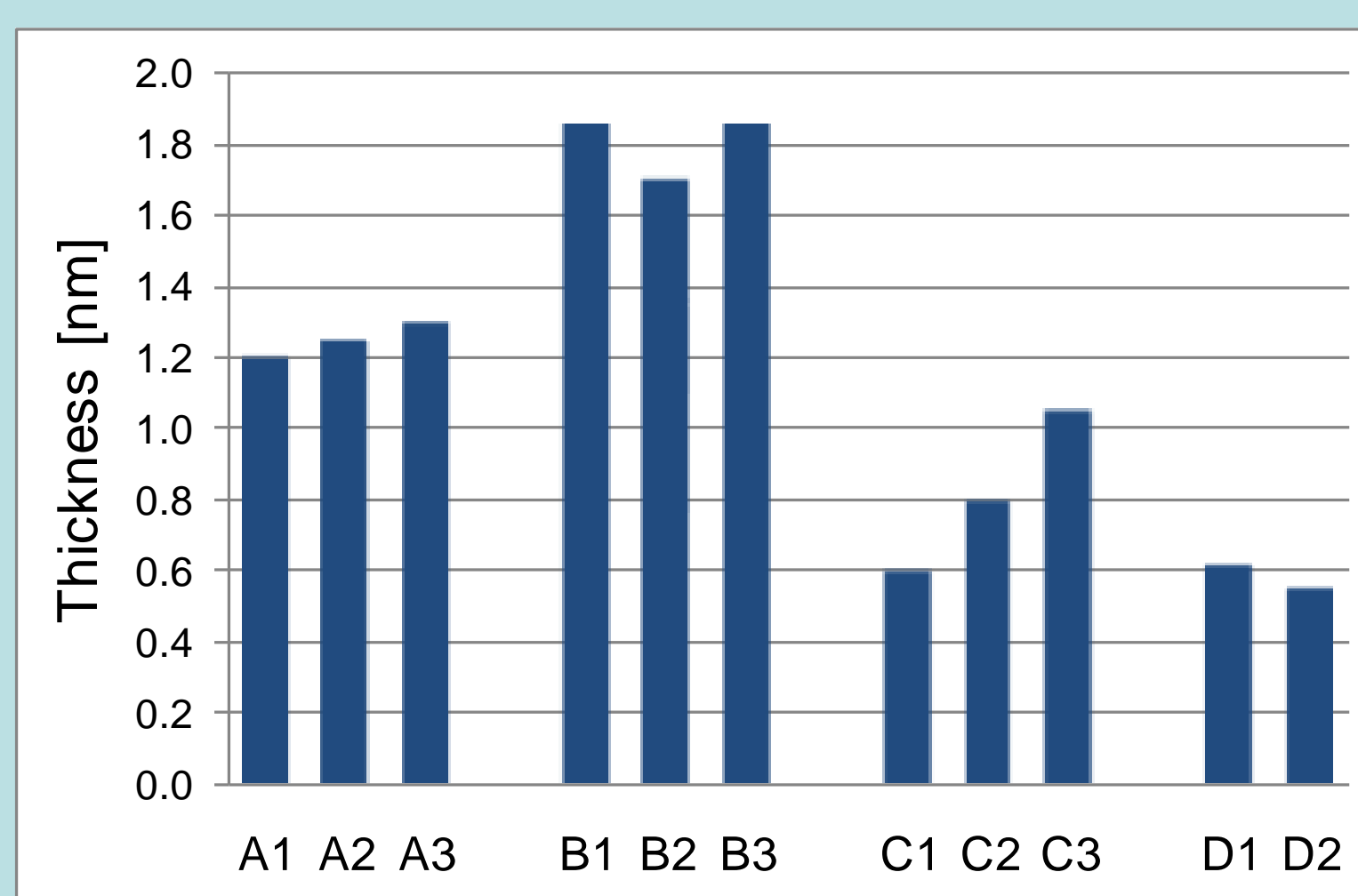
XPS is both used to identify nature of carbon deposition and check for non removable elements (e.g., trace amounts of N, S and other resist components.)



Note: Please see our poster entitled: Methods for assessing risk and measuring rates of optics contamination in high-throughput EUVL tools for correlation of XPS and ellipsometric C measurement.

## Results

Results for four resists: A, B, C, & D



Repeatability in the experiments with each of the four resists. (Note: Process control change in Resist C is suspected cause of variation; re-measurement of C underway.) Rates varied over a factor of three from the least to the most contaminating. No elements other than carbon detected above the  $\sim 1\%$  atomic concentration level.

## Conclusions

- NIST is establishing a witness plate testing facility that will meet the requirements for resist outgas testing for the ASML NXE.
- The NIST facility will soon be available to provide testing on selected key resist for resist developers.
- Multiple tests on several resists show good repeatability with sufficient process control.
- *In situ* ellipsometric imaging provides the first real-time measurement of evolution of contaminant across EUV intensity distribution.